P189 ↓

symposium

HUMAN VALUES IN A TECHNOLOGICAL SOCIETY

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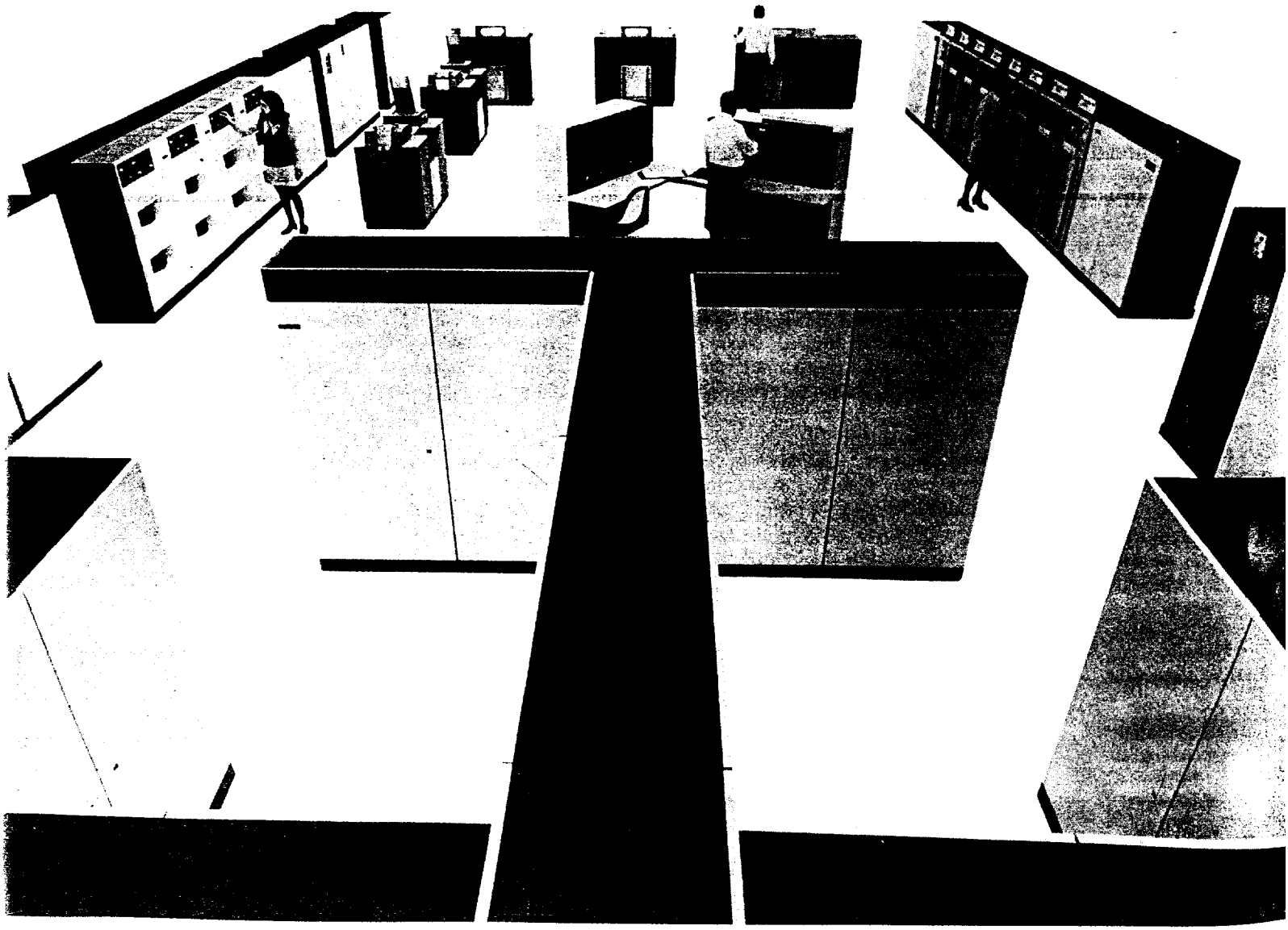

Joshua Lederberg

I. *Technology as Diabolism*

Monotheism, rooted in the Jewish religious tradition, and its most durable contribution to world culture, may seem to be irrelevant to a discussion of the human impact of modern technology. It may also be the most improbable allusion to expect from a geneticist. Consider, however, that monotheism liberated the human thinking from polytheism, or animism—the interpretation of the world and every process in it as the work of spirits, demoniacal or beneficent, fabricated essentially in man's image. Like man also they tend to caprice and unruliness.

Today we no longer deify the sun, the planets, the oceans, or the volcanoes. The One God of the Jewish tradition is inseparable from a universe ruled by law, and the skeptical strain of Jewish thought has never suffered scientific inquiry to be submerged under a demand for faith as the only legitimate source of knowledge.

Animism is still a convenient metaphor and shortcut to detailed analysis. It is convenient, at times, to regard a computer *as if* it were a quasi-intelligent being, responding to instructions and replying to inquiries like a willful child. The scientist can better design certain experiments if he visualizes a molecule as a perceptive organism, and thinks how it can "be aware of" the physical and chemical details of its local environment. The most literal acceptance of the Darwinian theory does not hinder the experienced biologist from speculating about the "purpose" of an organ, as a shorthand for a description of its evolution under the shaping influence of utility tested by natural selection. These are nevertheless metaphors, consciously preserved, which are well known to be able to lead to error, folly, and disaster, if they are misapplied to outside the range of the appropriate analogy. We do not allow computers to vote, and we do not expect man painlessly to improve his genetic makeup by merely wishing for the good, or needing to achieve it.

If we are not careful, the very theme of this symposium may lead us into serious moral and logical difficulties if we animize "technology," as so many authors have done. Useful metaphors may be drawn, for example, by hypothesis that a technological society behaves as if technology were an autonomous, malevolent force within it, i.e., a devil, but this is a subject requiring careful definition and investigation and it is promptly obscured by taking the metaphor for granted. The hypothesis can be made into a self-evident axiom, by labelling the collective imperfections of society as "technology"—as Roszak does, when he attributes *Playboy*'s derogation of meaningful sexual relationship to technocracy. The privilege of defining one's terms cannot be denied one's debating opponent, but such a definition does not help very much to discover who is a "technologist."

Among engineers and scientists, technology means the concrete application of scientific knowledge to problems of human significance. By extension it also means the organizational structure, the body of experience, the operational hardware, and the people who design and man it, and the end product. By further extension, technology may also be taken to mean science itself (knowledge about the natural world) and the community of scientists. The term technology conjures images of computers, suspension bridges, freeways, factories, nylon, jet planes, telephones, nuclear bombs, auto exhausts, pacemakers, television, penicillin, and DDT. These are the products that are unique to the technology of the present century. It should also include the abundance of our crops for food and fiber, fire, and the domestication of dogs and horses. It also means cheap paper back books, and a progressive relief of the burden of labor, a standard of living whereby youth can spend twenty years at their education, rather than go to the field or factory at twelve. It is in fact the whole texture of modern life, based on the level of industrial production that is possible only through the systematic application of scientific technology.

There is a great deal wrong with modern life, and our projections for the future are not more optimistic. The most cogent symptoms are the misapplication of technology. We have still to analyze the sources of that misdirection, for technology is a tool in the hands of man. This is neither to deny nor affirm the hypothesis that such a misdirection is inevitable, given the power of technology to amplify discrepancies of wealth and opportunity or the ideological impact of scientific skepticism on the shaping of human goals and aspirations. Nor can we give perfect marks to scientists and technologists for doing all that they might do to apply their special insights *about,* as well as *of,* science and technology for human welfare.

As a matter of personal honor, I must however protest the allegation that we live in a "technological society," if by that is implied that the major decisions are made by the consensus of technically and scientifically trained citizens. Exactly to the contrary! It was the President of the United States, against the advice and urging of many physicists, who decided to end the war against Japan in 1945 by dropping the A-bombs on Hiroshima and Nagasaki (a decision easiest to criticize in hindsight). Indeed it would be an intolerable arrogation of authority if scientists were to make such decisions against the informed conclusions of politically responsible leaders in a democracy. In recent months, scientists have been vehement in their denunciations of the SST and the ABM, and have been in the forefront of many other campaigns for the restoration of the quality of the environment. In the Soviet Union, they are the one irreducible focus of liberal thought, breaching national barriers to form the only effective world community functioning today.

THE anti-technologist can, of course, find many texts to support his condemnations. The architect, Albert Speer, is much quoted for his remark, "That some day the nations of the world may be dominated by technology—that nightmare was very nearly made a reality under Hitler's authoritarian system." But if we look more closely at his meaning, we find he refers above all to the radio and the telephone, systems by which a central authority could readily diffuse its commands without requiring the personal presence of the dic-

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tator. In fact, the Hitlerian regime did its utmost (and in many fields quite succeeded) in eradicating free scientific inquiry, allowing only that work judged relevant to the superiority of the German race to flourish. The technicians to whom Speer refers as blindly following orders are simply bureaucrats, but this is mainly a pun on technician/technology, at the same time as it refutes the concept of technocracy, i.e., government by the technical elite. Was Hitler an example of a pro-scientific ideology, or of the repudiation of reason?

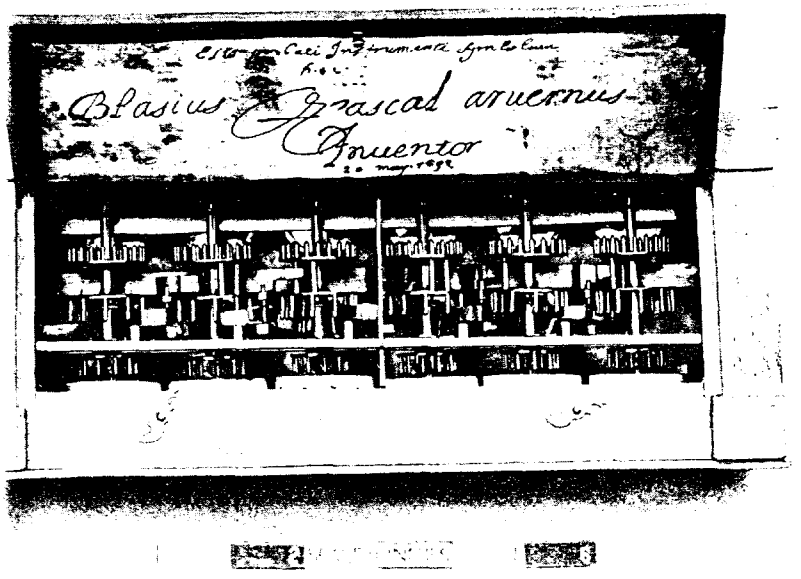
We could still profitably pursue parallel investigations that would help us to illuminate the sources of technopathy (the pathology of science and technology). Consider how many of the world's ills are attributable to *language* or to *law* out of control!

Language is of course the instrument of every deception and manipulation, as well as of man's utmost achievements. It is the means of reason and poetry alike, and confines them both. Should we not offer the same complaints against language that we do to technology? We could argue that language is the fundamental technique of the human species, which makes all others both possible and inevitable, through the processes of culture. And could we not make a parallel argument about law—how it liberates and enslaves man at the same time?

These analogies have too much substance to be dismissed but, even apart from the obscene confusion of technician and technocrat, a valid indictment emerges not in spite of, but as a consequence of, the exoneration of "technology." Technology, like law and language, is an institution whose realization depends on a particular community. Language on the contrary comes closest to being a product of the whole community, and we share a collective burden for its advance and misuse; we do not confuse the linguists who merely study language with the whole culture that invents and enriches it. Law, at the other extreme, is shaped by a body of men—the legislators, lawyers, and judges, who are professedly responsible to the culture, for its defects as well as its virtues. The legal, like other organized professions, is also ruled by its own code. This is far from perfect, but it still serves as a specific nexus of confrontation with the culture's demands and an indispensable protection to the morale and efficacy of its individual members. A definite though less tangible standard binds the behavior of the basic scientists, who are dedicated to the exhibition of publicly verifiable discoveries. The technologist, however, sells his services to the highest bidder—producing whatever design a customer has the means to support. (In Speer's case, Mephisto was Hitler as patron of architectural grandiosity.) He thereby transfers responsibility on to other shoulders, and, in this particular sense, the technologist (as distinct from scientist) is a mere technician serving another master. This elusive irresponsibility of the technologist, in the face of the enormous amplification of power his work conveys, may be the ultimate exasperation that enfuels the aquarian crusade. In one sense, "technology" is too ill-defined to be a legitimate target; in a deeper one, this is precisely the problem, given its undeniable disturbance to the complacency and placidity of life that we all cherish. Science is somewhat better organized as a community, but suffers from the same vacuum of responsibility for the technical elaboration of discovery.

It has then been suggested that technology, and by extension science, should be brought under more explicit social control. The real need may be to liberate it, i.e., to bring the institution of technology under more effective self-control, in the sense that medicine is, so that it may be collectively more responsible, while entrusting the detail of its work to the only community able to judge it well, itself.

Calculating machine invented by Blaise Pascal (1623-1662).



In the most extreme form, this would paralyze government and industry, if we meant that every technically trained employee in large organizations had the right and responsibility to judge every consequence of his efforts, and to sabotage whatever he deprecated. Furthermore, it goes beyond human reason to know the full outcome of any technological innovation. Shall we indict Alexander Graham Bell for the telephone that made Hitlerian totalitarianism possible? Shall we indict Mueller for DDT? And if so, because of damage to wildlife or because the control of malaria accelerated the population explosion? Would fewer lives have been ground up in war since 1945 had the airplane or the atomic bomb not been developed? Or more? And what in future?

There are nevertheless two major forms of socially useful control that a well organized profession of technologists would advocate and could enforce.

1. Major technological projects could be subject to disinterested review and licensure, to be certain that the intended profits in one area of the economy are not simply stolen, covertly, from another. This is the much discussed function of technological assessment—it deals with ques-

tions like the true cost of the SST or of electric power, taking full account of the threatened impairment of the environment. It can equally well concern the full costs of technological displacement or monotonization of labor, invasion of privacy, or any of the other cherished values of life. Almost all of the tangible grievances against technology can be covered by the extension of our economic system to take broader account of the values that make life worthwhile. It is furthermore within the power of a democratic society to insist on this—and scientists and technologists are just beginning to exercise their responsibility for systematic efforts to press public policy in this direction. The technology assessment need not all be delegated to a central authority, which may fall into the perennial ruts of the regulatory agencies, after their first flurry of reform. For example, we should consider the chartering of pluralistic consumer and environmentalist organizations to allow them a standing in court as representatives of large groups with grievances that cannot be pursued on behalf of any one individual. There is already considerable momentum today by groups for conservation law, and for consumer class actions, to make equitable law in the courts. They would be greatly helped, however, if they had a firmer legal standing to match that of the corporations and the labor unions. If such groups could recover compensatory and penalty damages, on behalf of their constituencies, we would see an entrepreneurship directed to balancing the interests of the consumer and inhabitant, to balance the entrepreneurship so effectively mobilized for the producer, distributor, and extractor.

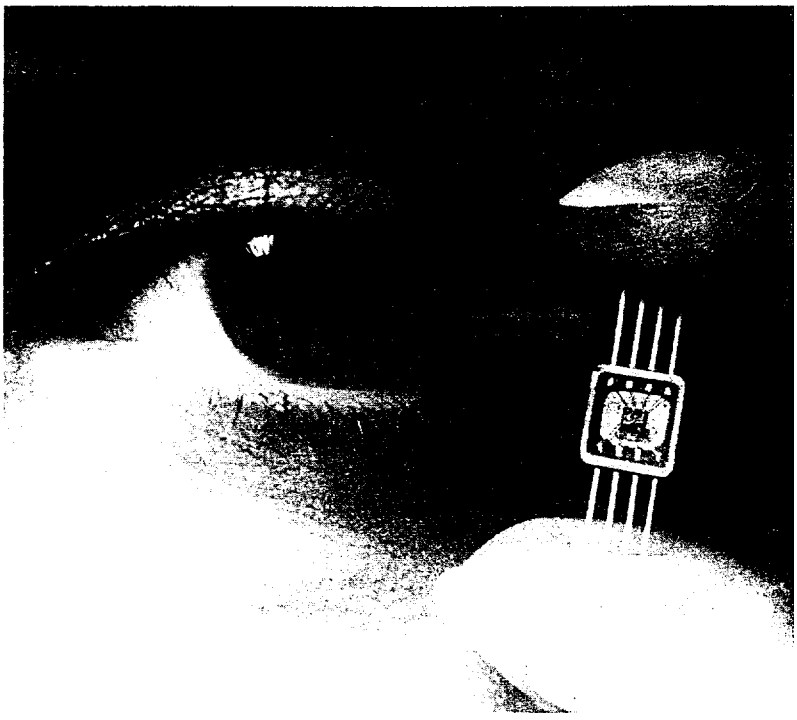
The development of effective technology assessment would, furthermore, dilute any need to "control" technological innovation at its scientific roots, which is both impractical and tyrannical in its implications.

2. Since technology assessment can only be applied where the costs can be anticipated, much research is needed at earlier stages of development to look for unforeseen troubles, and to develop antidotes. Without implying their right to specific control of the direction of technological changes, which is best left as a primary function of government support and regulation, and the market economy, technologists could insist that every project be taxed to support critical investigations of its consequences. Without the same kind of expertise that can invent a DDT or high energy fuels, we would not have known that DDT has deeper ecological effects than wiping out insect pests, or that LA smog is a consequence of unburned fuel in auto exhausts (rather than industrial pollution as would have been supposed by the naive observer). Technology has generated the environmental crisis, but science has discovered it and is indispensable for planning the rational remedies. The closer some of this countertechnology can be placed in time, place, and motivation to the original sources of trouble, the more efficiently the latter can be neutralized.

To be sure, there are equally insidious social and economic roots to the environmental-technological crisis, and these may not be redirected without some major readjustments in the distribution of wealth and in our ideology about the meaning of human life and work. However, political solutions to these problems will be accelerated if we can expose and document the social costs of particular technologies. There is nothing in the scientific ethic to oppose the re-equilibration of values, and a great deal in its technique to help support it. And the technologists will work even more happily for consensual goals than for narrower ones. The trouble is that the consensual judgment does not always coincide with the most advanced insight, e.g., on costs and pleasures of smoking cigarettes, allowing handguns to be freely available, investing in recreational and strategic defense systems, building freeways and dams, or making wars. The technologist is then caught in the middle, the most exposed target in the crossfire of social conflict. That the university has been the chosen battleground is partly a byproduct of its role as the seat of skeptical inquiry and to a smaller degree of misconceptions about the potency of academic opinion on national policy. But this is the game of liberals. Radicalism sees the university as a place where bewildered and resentful youths, with unformed ideologies, can most efficiently be recruited as shock troops of revolution, with expert assistance from indiscriminate doses of law and order.

As for the process of countertechnological inquiry, there are many kinds of incentives, taxes, and penalties that could encourage this kind of harmony, but none of them will be implemented if the technologists themselves do not respond to a *crise-de-conscience* in demanding it. At the very least, professional groups could accredit and rate technological organizations in accordance with their acceptance of this responsibility, and government contracting and tax policy could take account of the ratings. Needless to say, the federal establishment itself requires the closest attention: It is idiocy that radiobiological research within the AEC should have been cut back, as it has been, at a time

This molecular electronic circuit contains as many as 50 electronic components and is used in Minutemen ballistic missiles.



of increasing commitment to nuclear power development, and militant, if highly controversial, complaints about the reliability of standards of public exposure to radiation.

What of the basic scientist, the investigator who seeks "the truth for its own sake," though sharing the well-placed confidence that it will fit somehow into the machinery of technological power?

Modern science was founded as a response to questions of everyday life—the motions of the stars, the forces of gravity and of magnetism, the continuity and evolution of life, the composition of familiar matter. It promptly dispelled the remaining relics of animism, and did a great deal to shatter faith in revealed religion, insofar as these misguidedly justified themselves by assertions of a scientific nature. Well into the nineteenth century, science could be regarded as a liberating or counter-religion, wiping away many naive superstitions.

My own education, in the early thirties, was still colored by this function of science as a general world-outlook; but by then it was in fact already hopelessly fragmented into innumerable specialities in very poor communication with one another. By then already, a man who wished to understand nature could function far more efficiently by learning more of what was already known than attempting to carve new facts and interpretations out of the unknown. The process today has reached the point where very few scientific reports, apart from the jargon in which they are phrased, tell of insights that can have any significance to the layman—he would have to know more than he cares to about the background, and the telling of it would already be more informative, before he can understand why this particular fragment would interest the specialist.

The contemporary work of science is then hard to justify in terms of individual man's "need to know." Yet the body of scientific knowledge would be a sterile scholasticism if it were not constantly challenged and restructured. It still contains many inconsistencies, and merely to resolve them, as discovered, would already require constant resort to new tests. No two men can learn quite the same material; except for rote parroting, learning is already thinking and questioning and speculating, and, without the criterion of experimental verification, accumulated learning would again (as has happened at times in the past) become dry rot. It is fortunate then that the thrill of *discovery*, as much as of learning, motivates the researcher. We cannot ignore, as well, the motives of competition for prestige and for material rewards that help label scientists as part of the human breed.

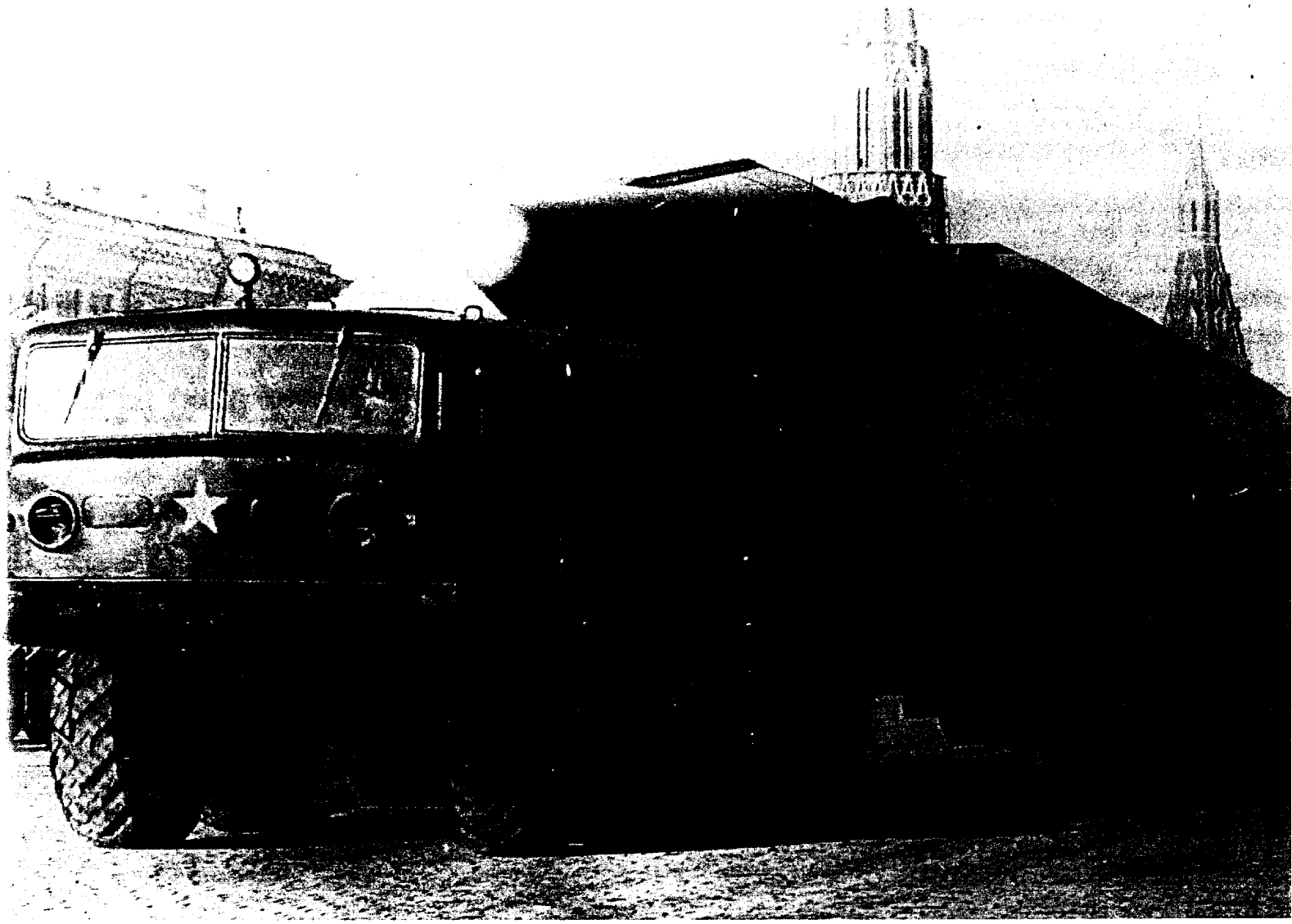
It is still true that contemporary science, in its fragmentation, tends to become ever more remote from the basic questions about nature that were its original invigoration. The effective practice of a particular science requires an extraordinary narrowness of focus, and rare indeed is the man whose inherent abilities and whose training leave any room for broader education and for philosophical and social wisdom commensurate with the overall impact that science has on the human condition. This pattern of use of talent has been too fruitful to warrant being disturbed, but everywhere the need is also seen for another kind of scholar, the contemporary humanist, who can understand science in its original terms, without being engulfed by the detail of one specialty; the man who, to use a now banal phrase, can also bridge the two cultures. The social need for this kind of intercultural moderator is not matched by any evident niches in the prestige and career structure of the academy, perhaps because there is no easy way to measure the quality of his performance, to select the good from the trash, as we pretend to do in the established studies. We may then stumble along with the help of the fallout from strict science of elder scholars, though age is at peril confused with wisdom.

This gap does manifest harm to the understanding of science by scientists themselves, as well as by non-professionals and in the corridors of political power. Even the methodology of science is impeded, for we still await a more rigorous formulation of scientific thinking in order to do science, scientifically; that is, in a way that would give us the full use of computer technology. With rare exceptions, scientists are remarkably naive about the logical foundations of experiments and verification and imprecise in their linguistics. That is to say, the scientific specialist usually has rather naive ideas about the process of science in the large, and is too enmeshed in detail to have a broad philosophical perspective about it. The challenge has been left to another discipline (the philosophy of science) which has remained so isolated from laboratory workers that, for example, few students majoring in a particular science will have been exposed to it.

The prestige of the scientific method, while still impugned in practical politics, is sometimes overrated and too mechanically applied in some social and humanistic studies. There are many areas whose complexity and inaccessibility to controlled experiment require more than quantitative measurement, especially when the phenomena under study are inherently not reproducible. Other kinds of insight and analysis may become even more important. Poetic and other intuitive visions may be especially important in opening whole new territories to the human intellect, in which scientific verification may still then play a measured part. For example, the revolution in human psychology ignited by Sigmund Freud was not a product of the kind of research that we would know how to program in science policy planning. Science itself is just such a process, and to speak of "a science of science" may be justifiable only insofar as one would define politics and history as "science." The arrogance of occasional claims that the scientific method can be used to prove some particular value system include the assignment of a value to the pursuit of science itself has certainly added to the embarrassment of science as an institution. It has also been criticized for being "value-free," but we do not demand a commitment to values of other instruments. We do demand this of men.

Is life really so intolerable today as a consequence of excessive technology? The main consequence of an improved standard of living has been the liberation of the many from absolute enslavement to their creature needs. We still have a proletariat, and we still have poverty in the U.S., but it is shrinking rapidly in absolute terms. Science and technology have, however, quite failed to provide any sense of the purpose of life, to go along with material affluence, except for the small elite minority that can find it in the processes of inquiry and invention. It is only by contrast with the possible future, not with historical reality, that technological culture also fails by measures of the quality of life in objective terms.

Faced with the task of clearing the residue of superstitious rubble through the nineteenth century, science may have preempted the task of religious reconstruction. But it can



Giant Soviet ICBM shown during celebration of the 50th anniversary of the Bolshevik revolution.

function only as a critic, and then mainly for the internal consistency of a rebuilt faith. I do not advocate science as a basis of religious commitment; but with all their faults, scientists are among the best-fulfilled people I know. There is at least no inconsistency between the practice of science and leading the good life. What scientists have rarely succeeded at is understanding themselves well enough to make their ethical and religious commitments a worthwhile source of leadership for many others, and especially among the young. Many of their pronouncements and self-reports need insightful translation. What can be left to isolated discovery by a pioneering generation must somehow be built into the education of the next one—for it to be the better equipped to make its own creative inventions.

II. *The Amelioration of Genetic Defect—A Case Study in the Application of Biological Technology**

The first part of this essay concerned some general issues of science and technology and of the general perception of their values. I now turn to some specific examples in genetics, the area of my own scientific expertise.

Few subjects pose more difficulties for rational discussion. Genetic research is promoted or chastised for its connections with such inflammatory themes as racism, the decline of the species, overpopulation, hidden genocide, religious debates on abortion and contraception, the plight of the individual in mass society, and "how many generations of idiots is enough."

On the other hand, the ultimate reach of genetics is vast, and relatively predictable. But the time scale of its implementation may be decades and centuries. Should we in fact spend much time worrying about the ethical implications of the genetic findings of the next century, when we must do this on the basis of a set of assumptions about the human condition that will surely change dramatically in every other way?

According to journalistic accounts, we will shortly be writing prescriptions for human quality to order. "Do you

*Revised from an article prepared for *Biosciences*, a publication of the American Institute of Biological Science.

want your baby to be eight feet tall, or have four hands? —just tell the geneticist, and he will arrange it for you." goes this line of advertisement. But the most sophisticated geneticist today is baffled by challenges like Huntington's disease. Will the son of an afflicted father be afflicted later in life? What can he do to assure that his own children will not have it?

Perhaps some year soon we will know enough at least to recognize the genotype before neuronal degeneration has been irreversibly set in motion. But our failure to be able to provide significant help today is a humbling reality next to the effusive, though justifiable predictions about future accomplishments.

What then of the bold claims for a brave new world of genetic manipulation? Their substance is grounded on the recent solution of many fundamental mysteries of genetic biochemistry. Many of the obstacles to genetic engineering, apart from the moral and political questions that this may pose, are technological; which is to say that their solution is consistent with our basic scientific knowledge of the gene. But this is as if to say that "merely technical obstacles" prevent building a land bridge from San Francisco to Honolulu. It is safe to predict that this enterprise will never eventuate, not merely because it would be a million times more costly than previous bridges, but rather because other challenges will compete for the energies and resources. And the presumed benefits will be achieved by the routes: The image of the transpacific bridge will persist as a metaphor, reminding us of technical achievements in other fields of transportation and communication and of the political prodigy of the evolution of a specific island from dependency to statehood.

Construction works, like bridges, are open to evaluation and judgment by common sense widely shared. Biotechnical projects are more likely to be cloaked in an esoteric jargon that defeats common sense justification. We may then hear the most absurd generalizations, like "whatever is technically feasible tends to get done."

Anyone who has actually labored to "do" anything knows that the more appropriate slogans are "almost nothing ever gets done, especially if it costs money." Or "when a need is generally perceived, articulately formulated, and wisely analyzed, the technical problems will be surmounted. But this will happen much sooner if a mass advertising campaign can be built around it."

WHERE then does the scientist fit into such a discussion?

He can fairly justify his life and work in terms of fundamental knowledge about nature. Studies on the implantation of nuclei into eggs of different genotypes are a rewarding approach to learning how genes function and how this relates to egg development. Were they done for the purported purpose of learning the technology of cloning in man, we would then be obliged to set a priority (positive or negative) on it from the standpoint of the human values that might justify or repudiate the investment.

Alternatively, the scientist can function as the actual or effective member of a technological team that will address itself to the solution of grave problems that encumber human welfare. Then we must and usually do insist that the problems are real ones and that technical solutions are credible. What is more often obscured is the need to examine all the side-effects, to inhibit the premature exploitation of new cures that may be far worse than the disease, to assure that as much sophistication goes into looking for the side-effects as was eagerly purchased for the primary solution.

What then are the *problems* to which genetic science can be applied? Some may think of rescuing man from the prospect of nuclear annihilation by recasting the genes for aggression, or acquiescence, that are supposed to predestine a future of territorial conflict. Even if we postulate for sake of argument that we knew the genetics of militarism, we have no way to apply it without solving the political problem that is the primary difficulty to begin with. If we could agree upon applying genetic (or any other effective) remedies to global problems in the first place, we probably would need no recourse to them in the actual event.

The converse argument applies to the gloomier predictions of totalitarian abuse of a genetic technology. The scenario of *Brave New World* is well-advertised by now, and no one doubts that a modern slave state would reinforce its class stratification by genetic controls. But it could not do so without having instituted slavery in the first place, for which the control of the mass media presents much more immediate dangers than knowledge of DNA. It is indeed true that I might fear the control of my behavior through electrical impulses directed into my brain, but (possibly excepting television) I do not accept the implantation of the electrodes except at the point of a gun, and this is the problem.

So much for the grand designs of genetic engineering. There remain the very real tragedies of genetic disease. The societal interest in preventing or ameliorating mental retardation and other forms of congenital malformation is obvious. (The true cost of lifetime maintenance of a 21-trisomy approaches a megadollar.) It is also entirely congruent with the needs of the family, and, if we believe in the nobility of man and the worth of *human* life, also of the afflicted child as well.

The most effective avenues of preventing genetic disease include (1) the primary prevention of gene mutations and (2) the detection and humane containment of the DNA lesions once introduced into the gene pool. The "natural" mutation process in man results in the introduction of a new bit of genetic misinformation once in every ten gametes. Most of the human cost of this "mutational load" is paid during early stages of fertilization and pregnancy, where it makes up a fair part of the total fetal wastage. But about 2 per cent of newborns suffer from a recognizable discreet genetic defect. This is just the tip of the iceberg; the heritability of many common diseases suggests that from one-fourth to one-half of *all* disease is of genetic origin, for there are important variations in susceptibility to the frankest of environmental insults.

The direct observation of human populations for evidence of environmental influences on mutation rates is an almost hopeless task. We have no way of managing the tangle of known and unknown environmental influences that bear on different individuals. Nor do we have tractable assays for the occurrence of new mutations, whose manifestation may be delayed (by transmission through heterozygotes) for many generations, or confused with malformations due to preexisting mutant genes, or to non-genetic causes.

Our only recourse is the laboratory experiment, with a convenient mammal, like the mice, and sometimes even more efficiently with viruses and microorganisms. Even so, only the most potent mutagens can be identified with mice, and many uncertainties will remain that cannot be resolved given possible differences in metabolism and transport, cell selection, intrinsic sensitivity, and the duration and style of life of the human versus the experimental species.

Once a mutation has been allowed to occur in a gamete, and this then participates in fertilization and the production of a new individual, we face a much more difficult problem in any effort at genetic hygiene. For now we must deal with the destinies of human individuals, not merely the chemistry of an isolated segment of DNA. Our problem, seen in the large, is compounded by every humanitarian effort to compensate for a genetic defect, insofar as this shelters the carrier from natural selection. So it must be accepted that medicine, even prenatal care (which may permit the fragile fetus to survive), already intrudes on the question "Who shall live?" the challenge so often thrust at rational discussions of policies that might influence the frequencies of deleterious genes. It is so difficult to do only good in such matters that we are best off putting our strongest efforts in the prevention of mutations, so as to minimize the heavy moral and other burdens of decision once the gene pool has been seeded with them.

We still cannot evade an evolutionary legacy of genetic damage that would remain with us for generations, even if all new mutation could be stopped by fiat. Our fundamental resources remain very feeble: In a few cases, we can diagnose the heterozygous carriers of recessive mutations, and the genetic counselor can then advise the prospective parents of the odds that they will have affected children. Where voluntary childlessness is unacceptable, it is also sometimes possible to monitor a pregnancy by sampling cells from the amniotic fluid. This can then enable the mother to proceed with confidence, or to request an elective abortion, on the basis of firm knowledge of the genotype of the fetus. We can expect a rapid extension of technical facilities for such diagnosis. At present, they are limited to examination of the chromosomes and to enzyme assays on cultured cells, which can diagnose a few dozen rare diseases, with varying degrees of reliability. We will surely be learning, during the next decade, how to use much more sophisticated approaches to the structure of the DNA and RNA of such cells for more basic diagnostic methods.

Another approach to constructive therapy, which may mitigate a variety of diseases, is an extension of the existing uses of specific virus strains. At present, their role in medicine is confined to their use as vaccines. This is a specialized example of the modification of cell metabolism by inoculated DNA, discovered empirically by Jenner, and still quite imperfectly understood (our ignorance being concealed by the conceptualizations of clinical virology, which still fail to explain just how a vaccine works—e.g., to state just which cells of the vaccinated individual are carrying the viral genetic information, and in what form.) We can visualize the engineering of other viruses so that they will introduce compensatory genetic information, into the appropriate somatic cells, to restore functions that are blanked out in a given genetic defect. As with vaccine viruses, this presumably will leave the germ cell DNA unaltered, and therefore does not attack the defective gene as such. If we can cope with the disease, should we bother about the gene? Or may we not leave that problem to another generation?

There has been much to-do about another theoretical possibility, "cloning-a-man," as might be done by the renucleation of a fertilized egg with a somatic cell nucleus, from an existing individual. Similar experiments have been successfully completed with frogs, and are being attempted with mice. Such experiments with laboratory animals will surely be very fruitful of basic scientific knowledge if the technique can be developed. It would also have enormous value in livestock breeding, just as cloning (propagation by cuttings) is a mainstay of horticulture. Until such experiments have been pursued in some depth with other animals, it is merely a speculative game to discuss applying such reproductive novelties to man. There is no urgent social problem to be addressed by such a technique. It does serve as a metaphor to indicate that future generations will have infinitely more powerful ways than we do to deal with whatever they may regard are socially urgent issues of human nature. We can therefore focus, more confidently, on dealing with the distress of individual human beings in the immediate generation. The metaphor also suggests that intrusive genetic engineering, if it is pursued for any other reason, will have plenty of policy problems to digest even before the "technology" has reached the point of detailed synthesis of genotypes by design.

Finally, medical scientists in general are fully aware of and have fully assimilated ethical concerns about the application of new techniques in man, by contrast to experimental animals. For a long time, it has been known that one could operate on the brain in such "interesting" ways as dividing the corpus callosum with the possibility of the development of autonomous "intellects" in the two hemispheres. It would be unthinkable to apply such surgical technology to man without the persuasion and conviction that it would be for the benefit of the patient-subject. We will not be given the benefit of the doubt in public discussions of such questions; there are many influential people who really believe that "anything feasible will be done," and we may have to restate the obvious many times in reviewing the ethical constraints on possible experimentation.

To return to the "clone-a-man" metaphor: In my view, we simply do not know enough about the question, at either a technical or an ethical level (and these are intertwined), to dogmatize about whether or not it should ever be done. Certainly it cannot be thought of, within the framework of our generally accepted standards of medical ethics, unless (1) we can make and communicate a reasonably confident prediction of the outcome and, more important, (2) it has the informed consent, and serves a reasonable humanitarian purpose, of and for the individuals who are involved. In genetic matters, this must include the interests of the prospective newborn, as well as of his parents, and of the community. If we demand that he be represented in person, then no one could reasonably be allowed to be born, whether by "natural" sexual fertilization, by the design of his parents, or otherwise. The specific question of "cloning-a-man" is almost the least important one I can think of; the one it opens up, who must be held to account for the next generation and how, may be the most.